Experiments on time-variation due to polarization and MMF shaking and results

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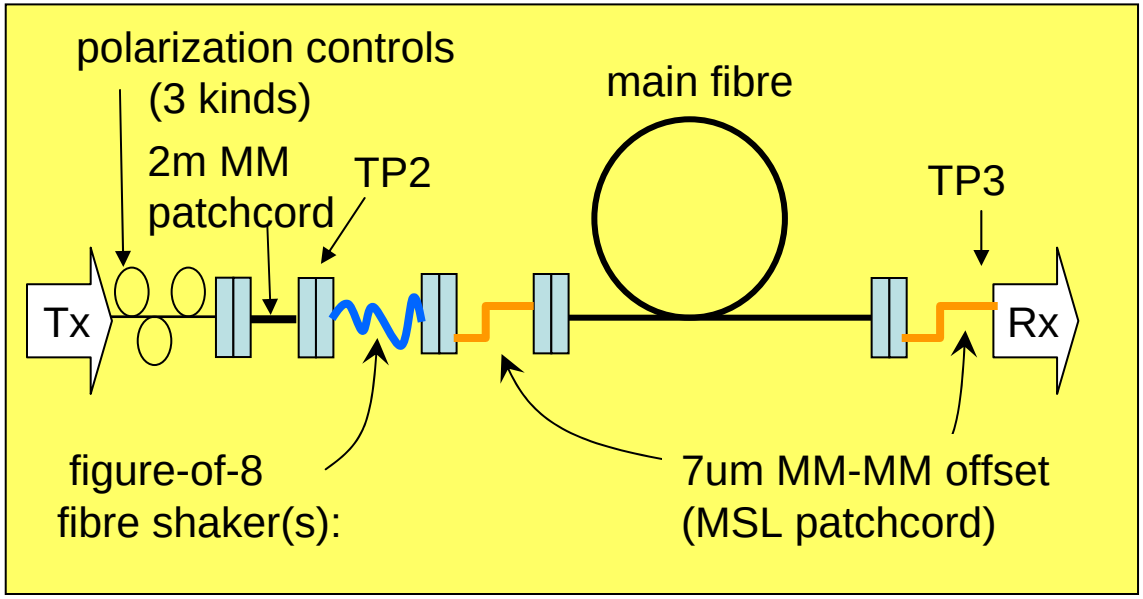
Big Bear Networks

Quasi static time variation measurements

- Aims
  - to support generalized model of fibre dynamic impulse response,
  - find worst case channel response to perturbation
  - use GR-63-CORE to predict channel response as function of frequency

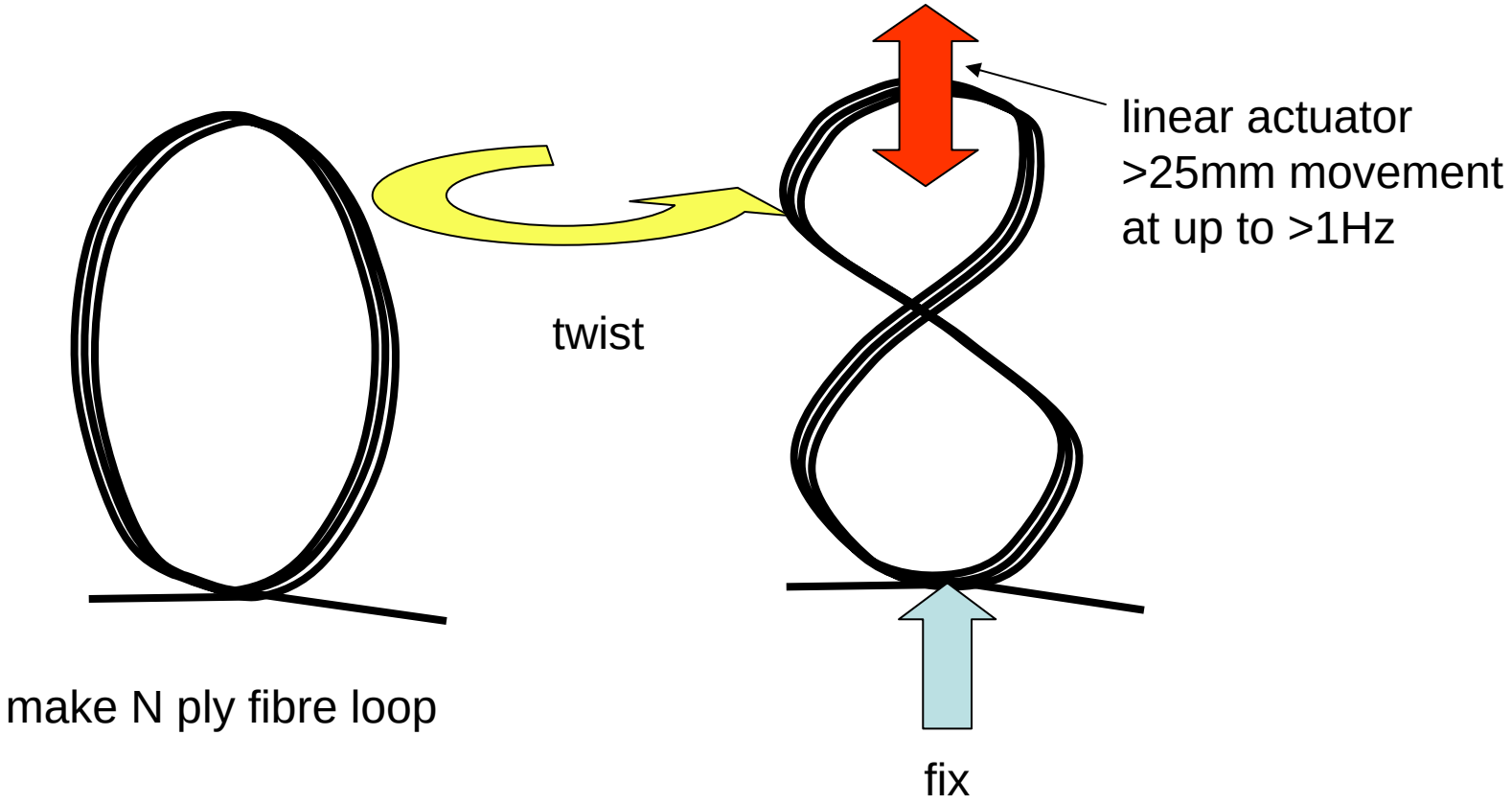
- Slow speed testing on FDDI fibres: 300m link with 2 worst case connector offsets
  - Impulse response measurements
    - Gain switched DFB laser source, 65um active area 8GHz receiver
  - Measuring:
    - time varying IPR 'envelopes'
    - quasi-static impulse response evolution
  - Separate polarization controls :
    - manual controller 'ears'
    - automatic polarization scrambler (HP11896A)
    - Figure-of-8 'shaker' in single-mode fibre (9ply, 120mm diameter)
      - emulates single mode patchcord perturbation
  - Separate MMF fibre shaker :
    - Figure-of-8 'shaker' multi-mode loop (9ply, 120mm diameter)

'Worst case link' test bed: two 7um offset connections



- 2 lossy connections emulated with offset spliced patchcords
  - one 7um offset before, one 7um after main fibre
- 3 additional MMF-MMF connections at input to main fibre (with nominal offset)
- Polarization controls and mechanical fibre 'shakers'

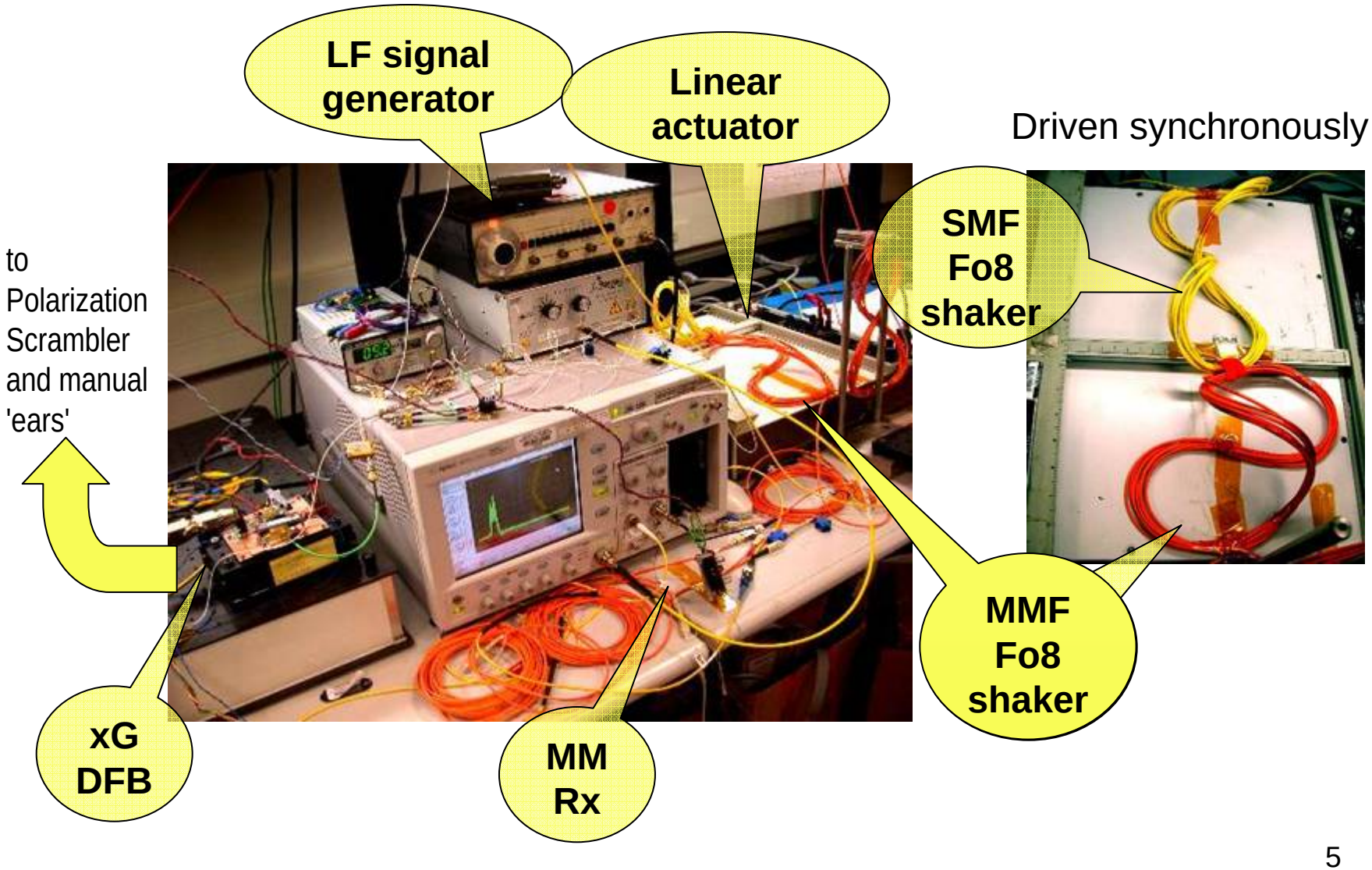
figure of 8 shaker



TIA-F04 recommends a mechanical fibre shaker made up of 3 independent figure-of-8 elements with N=3 for full fibre exploration.

This test bed aims to use similar total fibre length with 1 synchronous actuator to effect full fibre exploration

fibre 'shaker' test bed



IPR envelopes 1

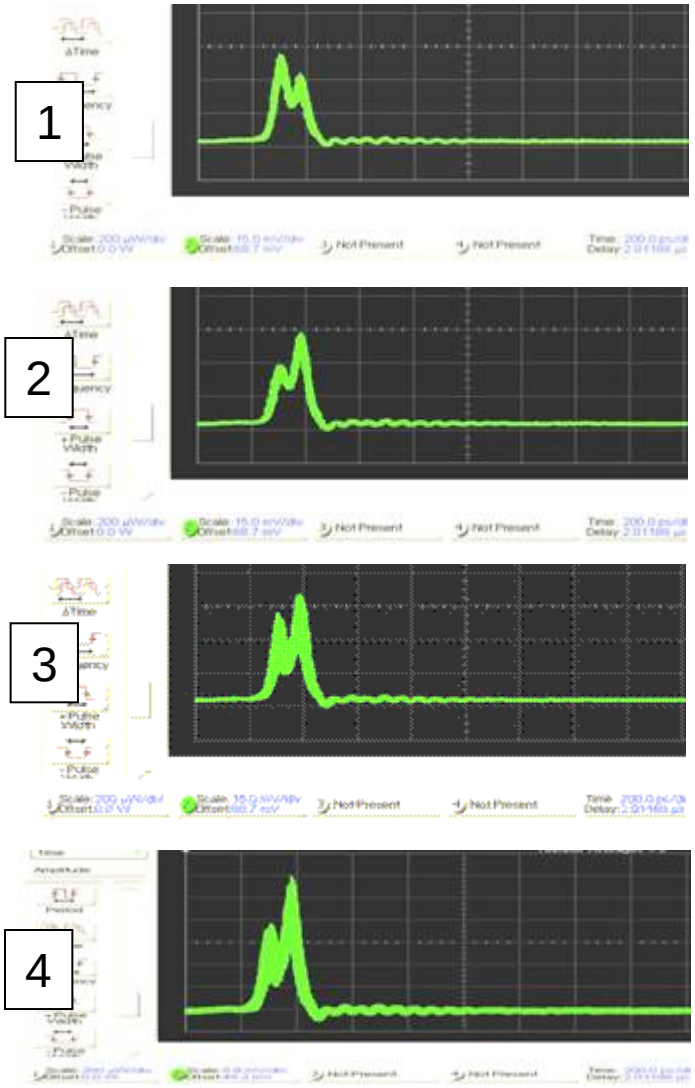
Polarization vs mechanical perturbation effect on impulse response

Envelopes of impulse response with 1 axis **mechanical fibre shaker on** and:

1) input polarization 1
2) input polarization 2
3) input polarization scrambler on
4) polarization scrambler off, and second mechanical shaker added

notes

- 1 horizontal axis fibre mechanical shaker may not be fully exploring mode power distribution
- adding 2nd scrambler in vertical axis has similar impact as polarization scrambler



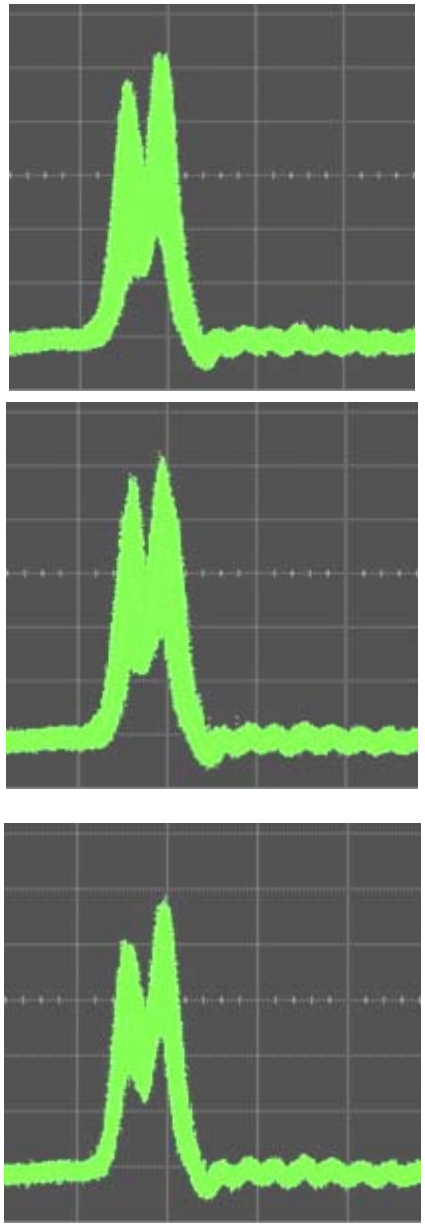
IPR envelopes 2

Fibre 1

Mechanical fibre shaker on and

1) input polarization manual ears operated
2) input polarization scramber on
3) synchronous input polarization shaker on

Similar exploration of IPR with all 3 methods



IPR envelopes 3

Fibre 2

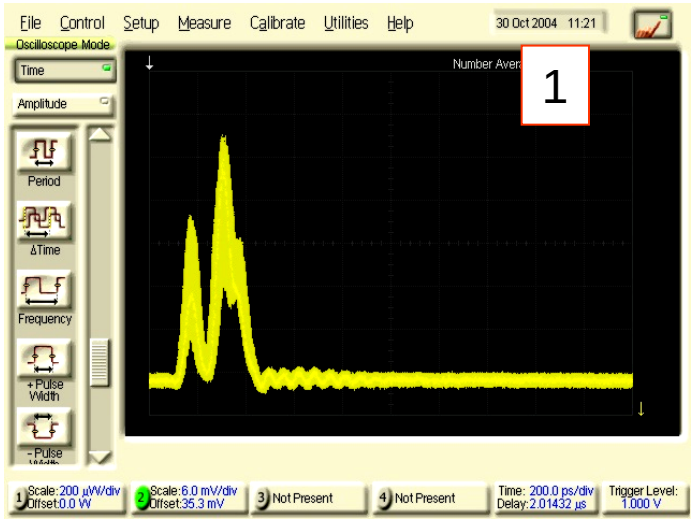
Mechanical fibre shaker on and

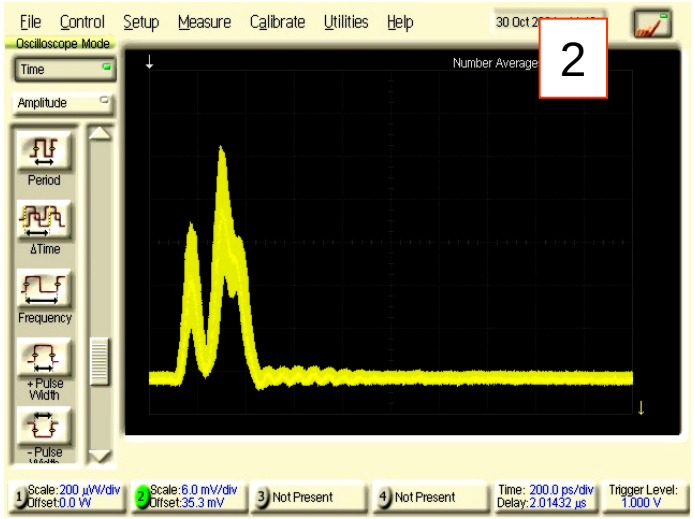
1) Polarization scramber on

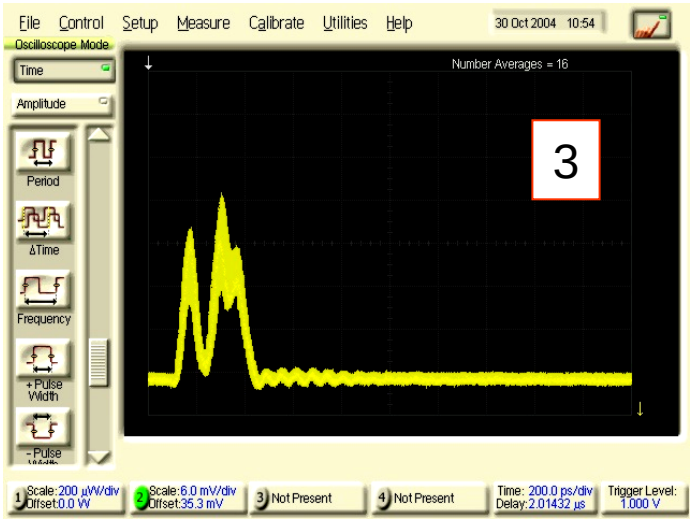
2) Synchronous input polarization shaker on (SMF Figure of 8)

Similar exploration of input conditions with both methods

3) Polarization only, MMF shaker off



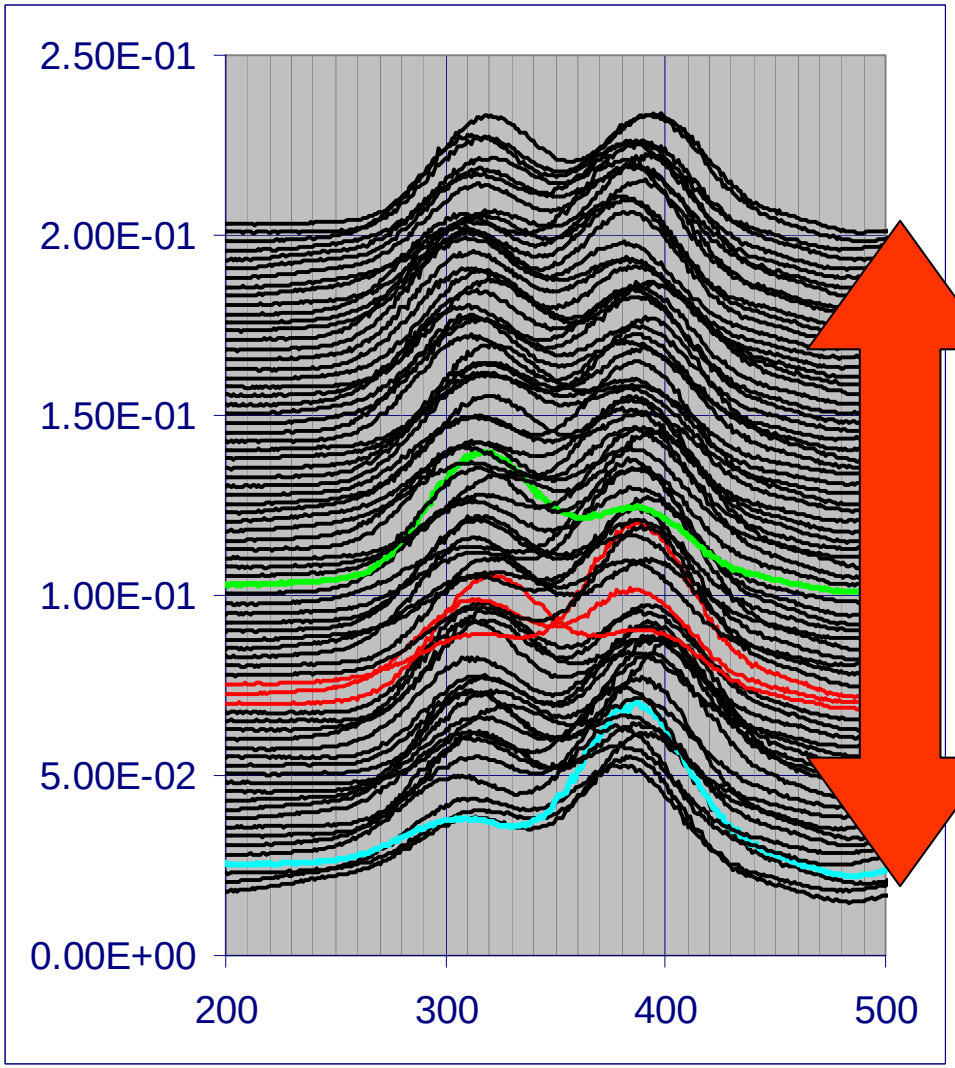




Conclusions from IPR envelope study

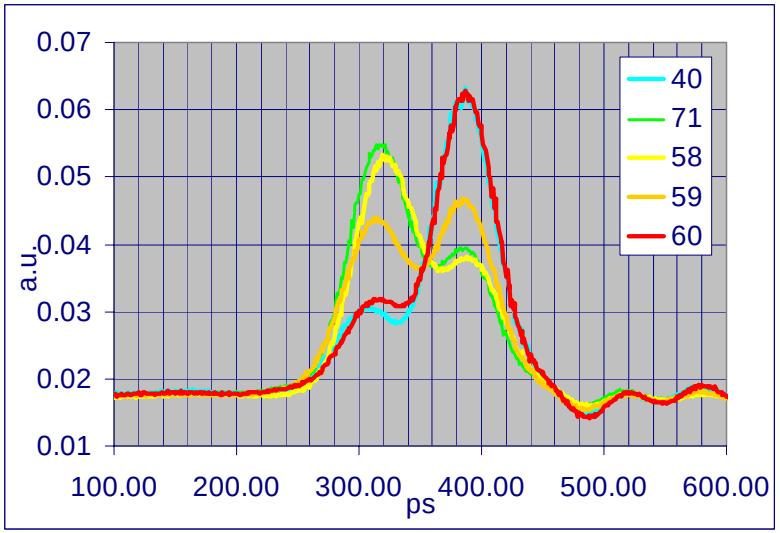
- Shows that polarization effect doesn't lead to any new or more difficult channel response than a thorough MMF shaker
  - The set of IPRs from polarization manipulation alone are a subset of those produced by a thorough MMF shaker
- Good IPR exploration is possible with combined synchronous SMF and MMF shakers
  - should be representative of a worst case perturbed patchcord (over 12 m of fibre is perturbed in the following experiments)

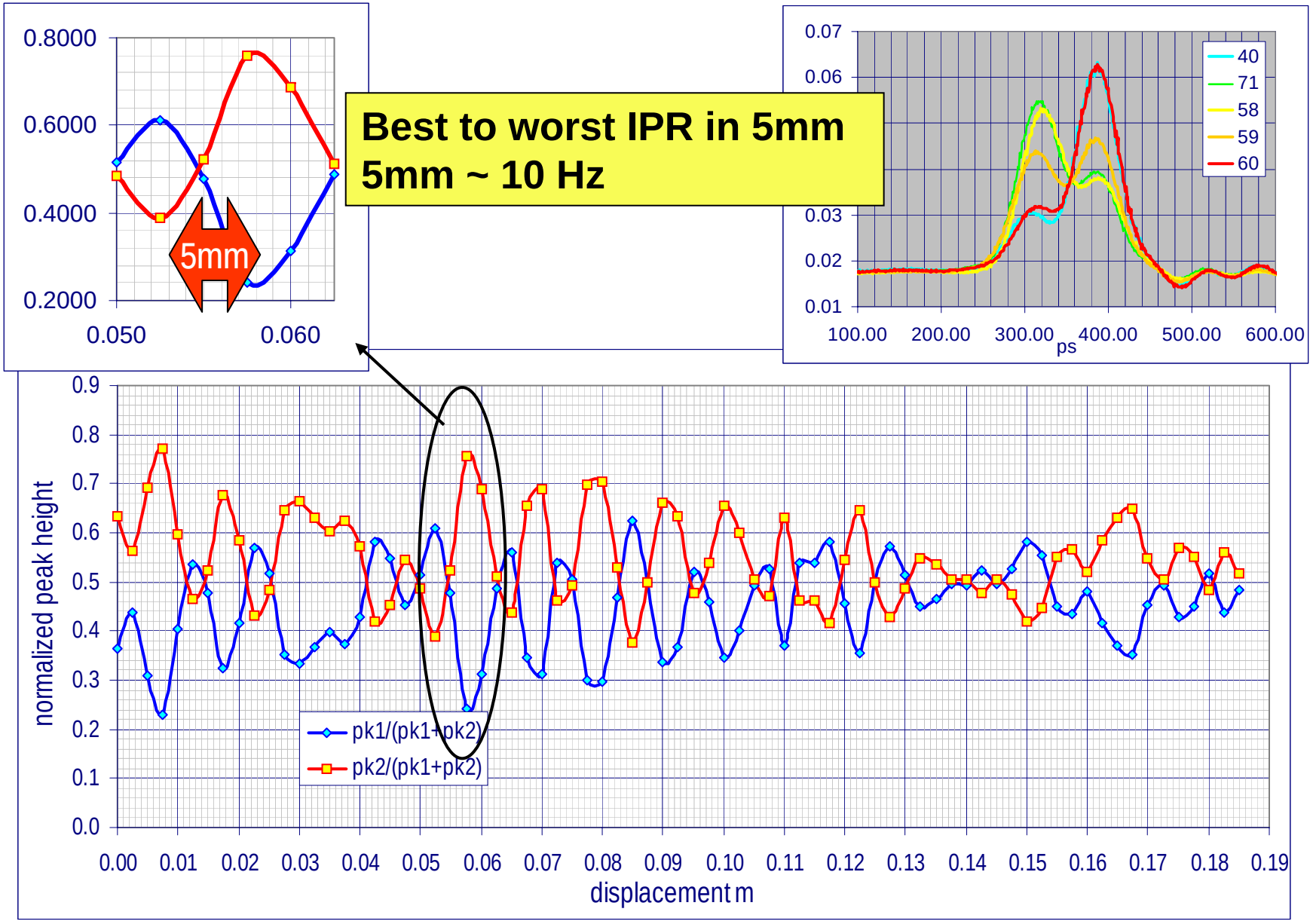
Quasi static IPR sequence, fibre 1



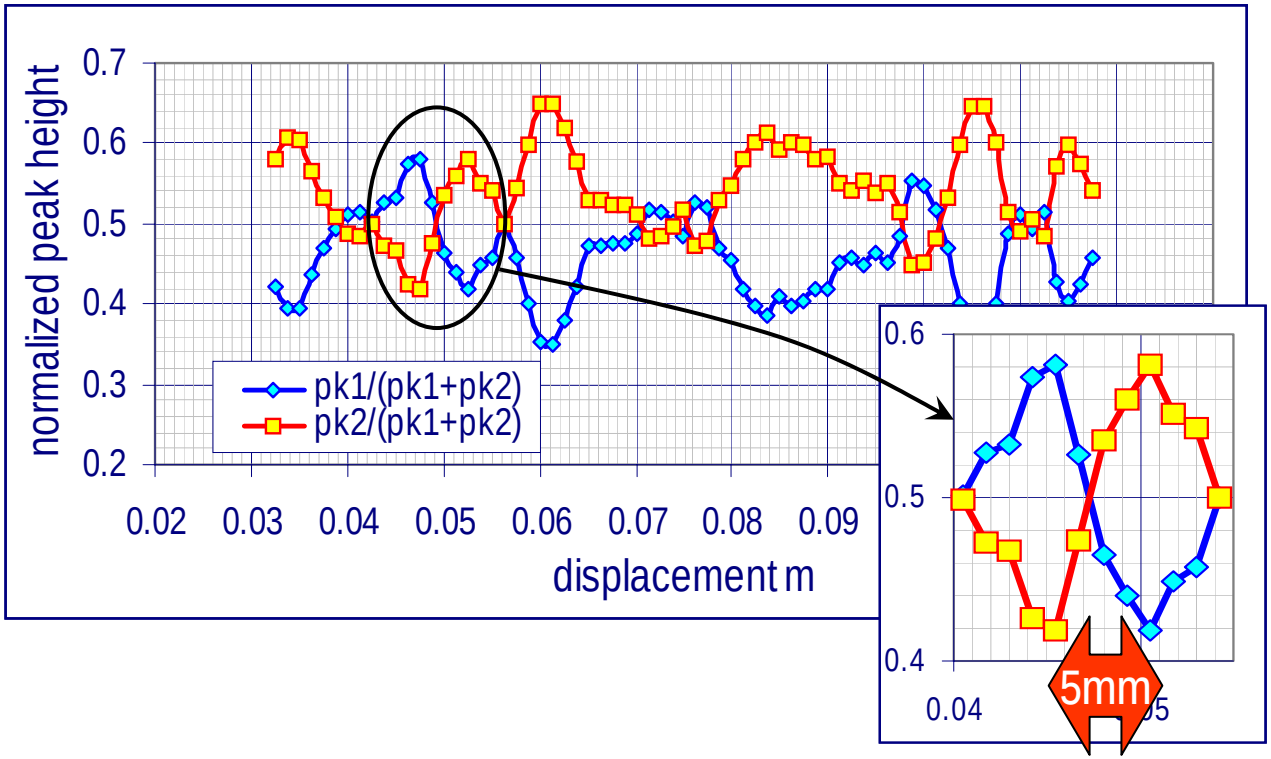
IPR can range between Post cursor, symmetric and pre-cursor

180mm total
Fo8 movement




Best to worst IPR in 5mm
5mm ~ 10 Hz
0.8000
0.6000
0.4000
0.2000
0.050
0.060
5mm
0.07
0.06
0.03
0.02
0.01
100.00
200.00
300.00
400.00
500.00
600.00
ps
40
71
58
59
60
normalized peak height
displacement m
pk1/(pk1+pk2)
pk2/(pk1+pk2)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19

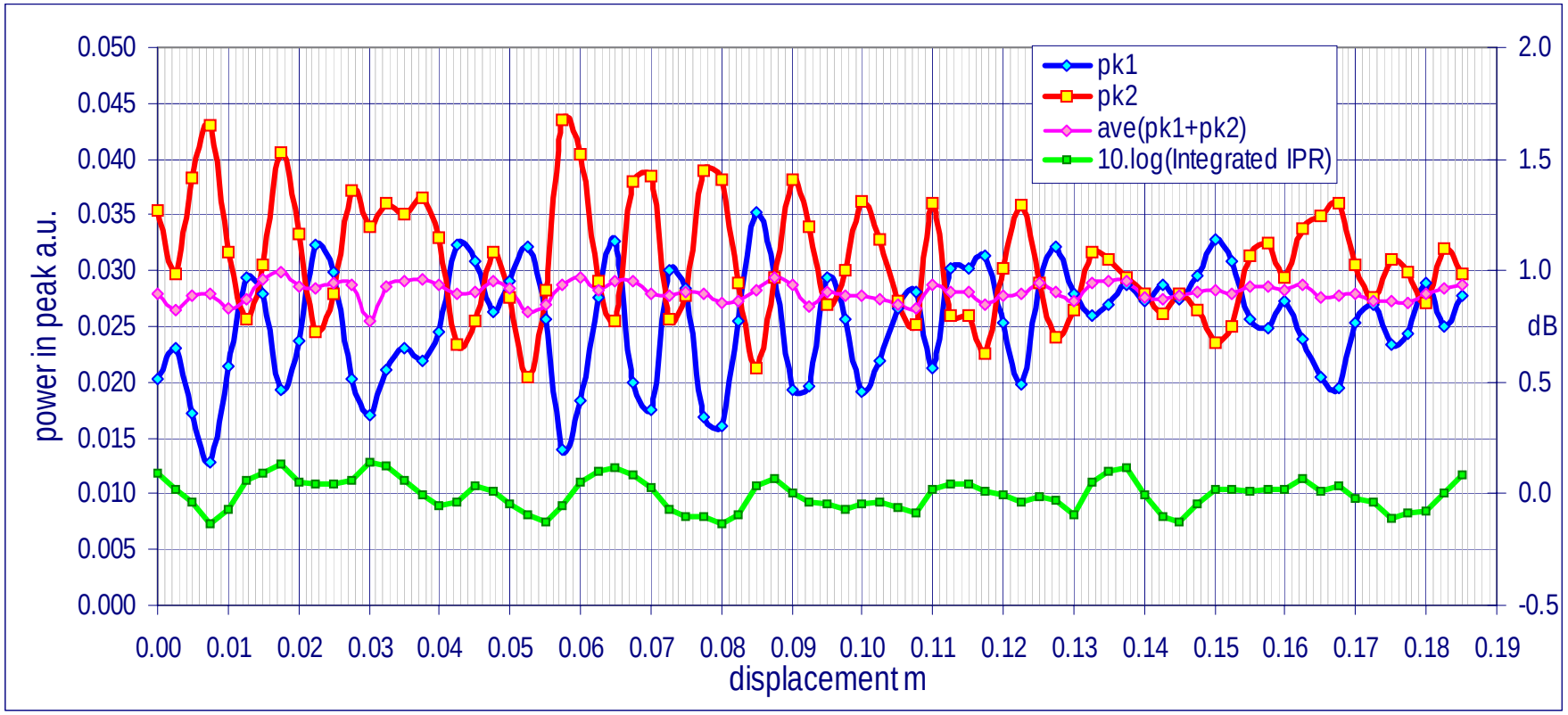
Higher spatial resolution sweep
1.25mm steps through fibre shaker displacement



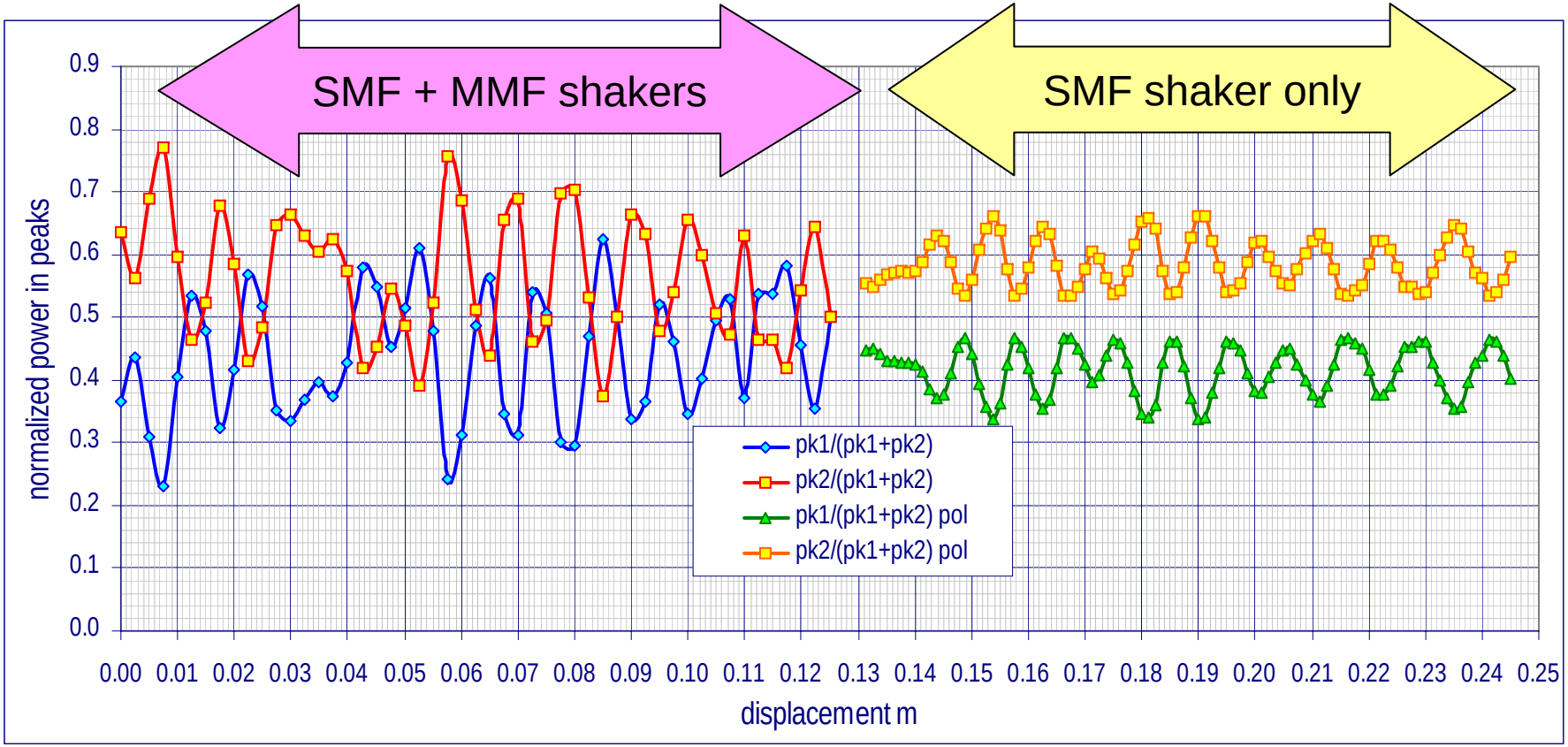
- Confirms previous measurements: worst-case post-cursor to pre-cursor evolution in ~5mm displacement,
  - no higher spatial frequencies
- Shows that 2.5mm steps gives adequate sampling of IPR evolution

Power conservation

- Integral of IPR as fibre shakers operated
  - maximum power variation ~0.3dB



SMF + MMF shaker vs SMF only



- Similar rate of IPR evolution with shaker displacement
- Polarization effect explores subset of IPRs explored with MMF + SMF shaker

Comments and conclusions

Polarization effect

- explores similar, smaller IPR space as thorough MMF fibre shaker
  - polarization IPR space is subset of thorough MMF fibre shaker
- power change in an IPR peak >> than mode selective loss
- although the theory behind the effect is not agreed, the effect can be bounded by experiment, and is included in combined SMF/MMF shaker

Quasi static IPR measurements

- Combined Synchronous SMF plus MMF shaker provides full IPR exploration
  - shrinks quasi static measurements to linear measurement domain
- representative of a worst case perturbed patchcord which includes polarisation and MMF mode mixing effects
- Selected fibre for study: 7um offset centre launch (2 peaked IPR) and range of causal to symmetric to anti-causal IPR variation possible
  - a worst case ? fewest excited mode groups means largest IPR variation likely
- Causal to anti-causal ('best to worst') IPR occurs in 5mm shaker movement
  - equivalent to 10Hz vibration rate at 1g following GR-63-CORE

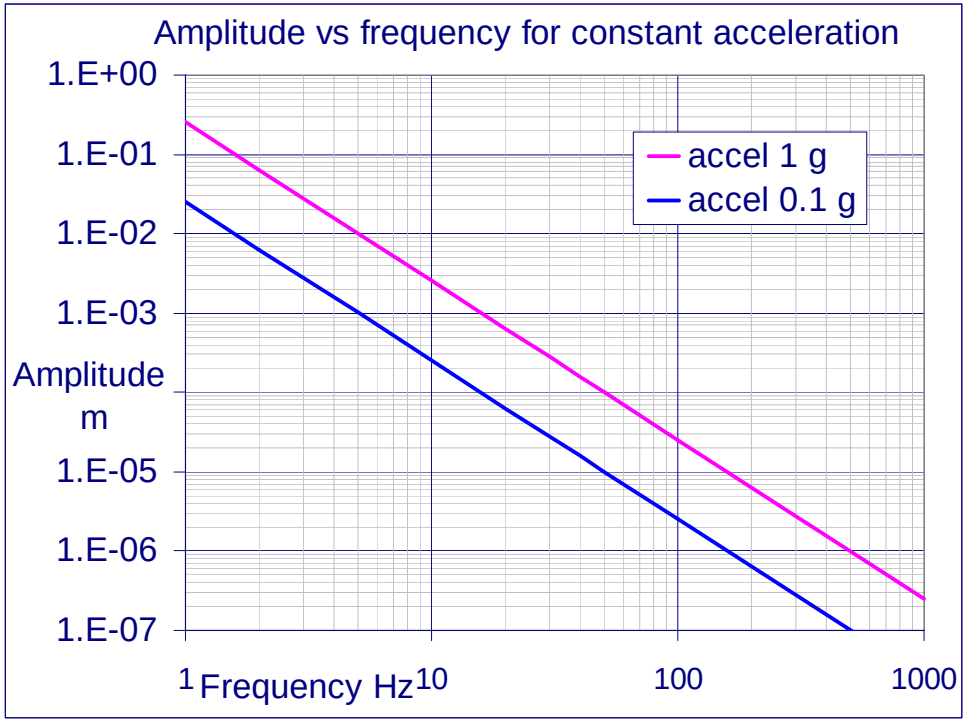
- Back up

Vibration tests representing office environment

Referencing GR-63-CORE

- Bellcore standard describing test conditions for telecomm central office equipment in a controlled indoor environment: vibration tests at constant acceleration (0.1g for frame assemblies, 1g for electronic sub-assemblies) from 5-100 Hz

- Vibration amplitude ~ **$1/f^2$**



  - 0.1g acceleration at 1Hz corresponds to 5cm p-p amplitude
    - comparable to TIA/EIA-455-203 fibre shaker
  - 1g acceleration at 1Hz corresponds to 50cm p-p amplitude
    - comparable to vigorous manual shaking of a fibre coil
  - 1g acceleration at 1kHz corresponds to 0.25micron amplitude - very small !

Suggests that low frequency range will be the test case of interest - supported by experiments